N95- 16055

HIGH TEMPERATURE POLYMER DIELECTRIC FILM-WIRE INSULATION

PRESENTED BY:
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HIGHLIGHTS OF PROGRAM ACCOMPLISHMENTS

- TRW IDENTIFIED AND DEMONSTRATED THE POTENTIAL OF TWO AROMATIC/HETEROCYCLIC POLYMERS TO HAVE AN OUTSTANDING AND SUPERIOR COMBINATION OF ELECTRICAL, THERMAL, AND CHEMICAL RESISTANCE PROPERTIES VERSUS STATE-OF-THE-ART KAPTON^{R} FOR SPACECRAFT AND/OR AIRCRAFT DIELECTRIC INSULATION APPLICATIONS (DATA PROVIDED IN TABLES THAT FOLLOW)

- FEASIBILITY WAS DEMONSTRATED FOR SUPPORTING/ENABLING TECHNOLOGIES SUCH AS CERAMIC COATINGS, CONTINUOUS FILM CASTING, AND CONDUCTOR WIRE WRAPPING, WHICH ARE DESIGNED TO ACCELERATE QUALIFICATION AND DEPLOYMENT OF THE NEW WIRE INSULATION MATERIALS FOR USAF SYSTEMS APPLICATIONS DURING THE MID- TO LATE-1990s

HIGHLIGHT PRELIMINARY WIRE INSULATION RESULTS

- CANDIDATE 2 WAS SELECTED FOR SELECTED WIRE WRAPPING AND TESTING BASED UPON BEST BALANCE OF PROPERTIES
- 14-GAUGE BARE COPPER WIRE WAS SUCCESSFULLY DOUBLE LAYER TAPE WRAPPED WITH CANDIDATE 2 COATED WITH TEFLON FEP ADHESIVE (0.0005-INCH THICK, ONE SIDE) EMPLOYING A PROCESS SIMILAR TO INDUSTRY METHODOLOGY USED FOR KAPTON FN
- CANDIDATE 2 INSULATED WIRE DEMONSTRATED HIGHER STABILITY THAN KAPTON IN AIR AND BREAKDOWN VOLTAGE RETENTION AFTER AGING (192 HOURS):

INSULATION MATERIAL	AC BREAKDOWN VOLTAGE (KV) BEFORE AGING	AFTER AGING	DECREASE (%)	INSULATION WEIGHT LOSS AT 300°C (%)
KAPTON	12.4	11.4	8	11
CANDIDATE 2	9.9	9.5	4	4

- THE TEFLON FEP ADHESIVE EMPLOYED FOR THE WIRE WRAPPING IS UNSUITABLE FOR LONG-TERM USE AT 300°C IN AIR (SIGNIFICANT LOSS OF POLYIMIDE TAPE ADHESION NOTED AFTER ~ 200 HOURS)
- DRY ARC/TRACK PERFORMACE OF CANDIDATE 2 INSULATED WIRE MAY BE ASSESSED IN LATE-1991 AT ANOTHER PRIME CONTRACTOR (NOT AS PART OF THIS PROGRAM)

CONCLUSIONS

BASED UPON THE PROGRESS ACCOMPLISHED IN PERFORMACE OF CONTRACT F33615-88-C-2909, THE FOLLOWING CONCLUSIONS ARE OFFERED:

- THE PROGRAM OBJECTIVE TO IDENTIFY AND DEMONSTRATE POLYMERIC DIELECTRIC FILMS POSSESSING A SUPERIOR COMBINATION OF ELECTRICAL, THERMAL, CHEMICAL AND PHYSICAL PROPERTIES TO THOSE POSSESSED BY KAPTON OVER THE TEMPERATURE RANGE OF -269°C TO +300°C HAS BEEN ACHIEVED. TWO POLYMERIC DIELECTRIC FILM MATERIAL CANDIDATES POSSESS THE FOLLOWING KEY SUPERIOR PROPERTIES TO KAPTON POLYIMIDE:
  - DIELECTRIC LOSS RESISTANCE AT 300°C,
  - OXIDATIVE AND VACUUM STABILITY AT 300°C,
  - HUMIDITY RESISTANCE AT 90°C/100% RH,
  - ULTRAVIOLET RADIATION RESISTANCE AT 25°C AND
  - BASIC SOLUTION (pH 10) HYDROLYSIS RESISTANCE AT 93°C,
- THE MORE MATURE DIELECTRIC FILM MATERIAL, CANDIDATE 2, POSSESSES HIGHER DRY ARC/TRACK RESISTANCE THAN KAPTON
- THE OVERALL PROPERTIES OF CANDIDATE 1 (IN THE DEVELOPMENTAL STATE IN FILM FORM) GENERALLY COMPARE VERY FAVORABLE WITH CANDIDATE 2 (AN OPTIMIZED FILM PRODUCT); OPTIMIZATION OF CANDIDATE 1 FILM MAY LEAD TO SUPERIOR FILM PROPERTIES TO CANDIDATE 2,
- CERAMIC COATINGS HAVE THE POTENTIAL TO SIGNIFICANTLY IMPROVE THE BREAKDOWN VOLTAGE AND/OR DRY ARC/TRACK RESISTANCE OF HIGH PERFORMANCE DIELECTRIC FILM MATERIALS
- CANDIDATE 2 FILM CAN BE CONVERTED INTO TAPE WRAPPED WIRE INSULATION BY THE SAME COMMERICAL PROCESS CURRENTLY EMPLOYED TO PRODUCE KAPTON WIRE AND POSSESSES SUPERIOR 300°C OXIDATIVE STABILITY VERSUS KAPTON; HOWEVER, AN IMPROVED FILM WRAP TAPE ADHESIVE OVER TEFLON™ FEP MUST BE IDENTIFIED AND DEVELOPED TO ACHIEVE THE TRUE POTENTIAL OF THE NEW WIRE INSULATION CANDIDATES FOR EXTENDED SERVICE AT 300°C.

PROGRAM OVERVIEW

- PROGRAM TITLE: HIGH TEMPERATURE POLYMER DIELECTRIC FILM
- CONTRACT NUMBER: F33615-88-C-2909
- CONTRACT VALUE: $298K
- TECHNICAL PERIOD OF PERFORMANCE: THIRTY MONTHS (NOVEMBER, 1988 THROUGH MAY, 1991)
- TECHNICAL TASKS

TASK	TITLE	STATUS
1	SCREENING AND TEST PLAN DOCUMENTATION	COMPLETED
2	DEVELOPMENT AND DETAILED TESTING	COMPLETED
3	PRODUCT OPTIMIZATION	COMPLETED
4	WIRE INSULATION AND TESTING	COMPLETED
-	REPORTING	FINAL DRAFT SUBMITTED

- AERO PROPULSION AND POWER DIRECTORATE PROGRAM MANAGER: JOHN G. NAIRUS
- TRW PROGRAM MANAGER: ROBERT J. JONES

KEY PROGRAM PARTICIPANTS

ORGANIZATION	KEY ROLE	TASK PARTICIPATION
TRW	PRIME CONTRACTOR PERFORMED ALL EXPERIMENTAL WORK EXCEPT THAT CONDUCTED BY VENDORS (SEE BELOW)	ALL (1 THROUGH 4)
LAWRENCE TECHNOLOGY DIVISION OF CAMCO (FORMERLY TRW OILWELL CABLE DIVISION)	FILM ELECTRICAL PROPERTY TESTS, WIRE WRAPPING AND INSULATED WIRE TESTING	ALL (1 THROUGH 4)
WYLE LABORATORIES	CRYOGENIC IMMERSION TESTS	1
REXHAM CORPORATION	CONTINUOUS FILM CASTING	3
SHELDAHL CORPORATION	PRODUCED CERAMIC PROTECTIVE COATING ON FILMS	3

PROBLEM

STATE-OF-THE-ART HIGH PERFORMACE, AROMATIC/HETEROCYCLIC DIELECTRIC FILM INSULATION MATERIALS (EXEMPLIFIED BY KAPTON) CURRENTLY SUFFER SEVERAL CRITICAL DEFICIENCIES:

- SIGNIFICANT DIELECTRIC LOSS AS A FUNCTION OF TEMEPRATURE FROM APPROXIMATELY -80°C TO +100°C AND ABOVE APPROXIMATELY +200°C,
- SIGNIFICANT DEGRADATION IN AIR (300°C AND ABOVE), HUMIDITY (95% RH) AND ULTRAVIOLET RADIATION (RT AND ABOVE)
- POOR RESISTANCE TO ARCING/TRACKING FAILURE.

OBJECTIVE

IDENTIFY AND EVALUATE COMMERCIALLY AVAILABLE ADVANCED AROMATIC/HETEROCYCLIC FILM FORMING POLYERS HAVING IMPROVED ELECTRICAL, THERMAL, HUMIDITY/CHEMICAL RESISTANCE PROPERTIES OVER KAPTON® FOR WIRE INSULATION APPLICATIONS IN FUTURE SPACECRAFT. IDEALLY, THE NEW INSULATION MATERIAL WILL BE EQUALLY SUPERIOR FOR AIRCRAFT POWER GENERATION APPLICATIONS. THE GOAL PERFORMANCE TEMPERATURE RANGE IS FROM -260°C TO ≥ +300°C.

APPROACH

SELECT FIVE PROMISING CANDIDATES (BASED UPON AVAILABLE DATA) FROM HIGH TEMPERATURE RESISTANT, COMMERCIALLY AVAILABLE, FILM FORMING POLYMERIC MATERIALS; CONDUCT KEY ELECTRICAL, THERMAL AND CHEMICAL PROPERTY TESTS EMPLOYING KAPTON® AS THE CONTROL FILM MATERIAL; CONDUCT TEST PROGRAM ACCORDING TO THE FOLLOWING SEQUENTIAL TASK

TASK	KEY TESTS	OUTPUT OF TASK
1	SCREEN FIVE CANDIDATES FOR: • HIGH TEMPERATURE PROPERTIES • LOW TEMPERATE FLEXIBILITY • INITIAL ELECTRICAL PROPERTIES • INITIAL CLEANING SOLVENT STABILITY • OXIDATION RESISTANCE	DOWN SELECT TO THREE PROMISING CANDIDATES; DOCUMENT TEST PLAN FOR CONDUCTING REMAINDER OF PROGRAM
2	PERFORM DETAILED TESTS ON THREE CANDIDATES FOR: • VACUUM RESISTANCE • HUMIDITY RESISTANCE • ULTRAVIOLET RESISTANCE • BASIC AND POLAR FLUID RESISTANCE	DOWNSELECT TO TWO MOST PROMISING CANDIDATES
3	PERFORM PROCESS OPTIMIZATION AND TEST ON TWO CANDIDATES IN TERMS OF: • CERAMIC COATINGS • CONTINUOUS CASTING OF FILM	DOWNSELECT TO BEST CANDIDATE
4	WRAP FILM ON WIRE AND TEST FOR: • ELECTRICAL PROPERTIES BEFORE AND AFTER AIR AND HUMIDITY AGING	WIRE TEST DATA/SAMPLES

HIGHLIGHT FILM DATA SUMMARY (TWO MOST PROMISING CANDIDATES VERSUS KAPTON CONTROL)

PROPERTY TYPE ASSESSED	SPECIFIC PROPERTY TEST	GOAL PROPERTY VALUES	PROPERTY TEST RESULTS		
			KAPTON	CANDIDATE 1	CANDIDATE 2
ELECTRICAL	DIELECTRIC CONSTANT (1000 HZ)				
	• RT	≥3.5	3.1	3.1	3.3
	• 300°C	≥3.2	2.8	2.9	3.3
	DISSIPATION FACTOR (1000 HZ)				
	• RT	≥0.003	0.001	0.001	0.002
	• 300°C	≥0.005	0.003	0.004	0.003
	BREAKDOWN VOLTAGE (RT, KV/MIL)				
	• AC UNCOATED	>5.0	7.7	6.1	6.1
	• AC CERAMIC COATED	>5.0	7.8	6.4	6.1
	• DC UNCOATED	>10.0	11.6	12.4	10.2
	• DC CERAMIC COATED	>10.0	12.7	12.9	10.2
	ARC/TRACK - MEDIAN VALUES (SECONDS TO FAILURE)				
	• UNCOATED	>>180	181	129	192
	• CERAMIC COATED	>>180	183	141	215

HIGHLIGHT FILM DATA SUMMARY (TWO MOST PROMISING CANDIDATES VERSUS KAPTON CONTROL CONTINUED)

PROPERTY TYPE ASSESSED	SPECIFIC PROPERTY TEST	GOAL PROPERTY VALUES	KAPTON	CANDIDATE 1	CANDIDATE 2
THERMAL	MELT (OR DECOMPOSITION) TEMPERATURE (Tm °C)	>400°C	>400	>400	>400
	GLASS TRANSITION TEMPERATURE (APPARENT Tg, °C)	>300°C	340	350	318
	CHAR YIELD IN VACUUM AT 800°C (%)	LESS THAN KAPTON	47	32	53
	LOW TEMPERATURE FLEXIBILITY (IMMERSION IN LIQUID HELIUM AT -269°C)	RESIST CRACKING (EQUIVALENT TO KAPTON)	NO EFFECT	NO EFFECT	NO EFFECT

HIGHLIGHT FILM DATA SUMMARY (TWO MOST PROMISING CANDIDATES VERSUS KAPTON CONTROL CONTINUED)

PROPERTY TYPE ASSESSED	SPECIFIC PROPERTY TEST	GOAL PROPERTY VALUES	KAPTON	CANDIDATE 1	CANDIDATE 2
ENVIRONMENTAL EXPOSURE	WEIGHT LOSS IN AIR AT 300°C FOR 1000 HOURS (%)	<5%	14	4	2
	WEIGHT LOSS IN HUMIDITY AT 90°C/100% RH FOR 1200 HOURS (%)	<1%	SAMPLES FAILED	0.4	0.6
	WEIGHT LOSS IN UV LIGHT (365 NM) AT RT FOR 1000 HOURS (%)	LESS THAN KAPTON	6.7	1.4	0.5
	WEIGHT LOSS IN VACUUM (1 TORR) AT 300°C FOR 500 HOURS (%)	LESS THAN KAPTON	1.7	1.2	1.0
	WEIGHT LOSS IMMERSED IN PH 10 BASIC SOLUTION AT 93°C FOR 96 HOURS (%)	LESS THAN KAPTON	2.6	1.3	1.2
	WEIGHT CHANGE IN METHYLETHYL KETONE AT 90°C FOR 500 HOURS (%)	<5% LOSS OR GAIN	+5.8	-2.9	-1.7